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SHOWER PARTICLE MULTIPLICITY DISTRIBUTIONS FOR COLLISIONS OF 200-400 GEV/C PROTONS WITH EMULSION

UDC 531.715

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Abstract. *In this work we study the asymmetry in the appearance of even and odd number of secondary pions in interactions of 200, 300 and 400 GeV/c protons with emulsion nuclei. We found that in so-called 'white stars' the number of events with odd pion multiplicity cannot be explained by the mechanism of coherent particle production. We also discuss the behavior of this asymmetry as a function of the multiplicity of heavy particles and the number of fast protons for the total sample of events.*

Keywords: *even-odd effect, high-energy hadron-nucleus collisions*

1. INTRODUCTION

In the emulsion technique, all secondary particles emitted in nuclear reactions at very high energies are classified as [1]:

- shower particles (*s*), mainly pions, with very light tracks,
- fast protons, (*g*), with gray tracks, and
- slow protons and heavy fragments, (*b*), whose tracks are black.

The total number of slow and fast protons and heavy fragments, $n_h = n_g + n_b$, is usually taken as the measure of the excitation of the target nucleus, while the number of fast protons, n_g indicates the value of the impact parameter. If in the interaction only shower particles are emitted, the total number of gray and black tracks is zero, and such type of event is called a 'white star'. We can suppose that 'white stars' correspond to the first stage of the interaction or to the peripheral processes.

The multiplicity distributions of all kinds of particles and their relations, in interactions of 200, 300 and 400 GeV/c protons with emulsion nuclei, are investigated earlier [2,3,4]. In our recent paper [5], the special attention was paid on the multiplicity

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and angular distributions of secondary pions in the 'white stars'. Experimental results were compared with Monte Carlo (MC) simulations based on Quark Gluon String Model (QGSM) [6]. In general, we found good agreement between experimental data and results of MC simulations. However, QGSM was not able to explain the rate of the 'white stars' events and the 'even-odd effect' in this sample of events. The 'even-odd effect' means that at low multiplicities, the production of odd number of pions is much more probable.

The goal of this paper is to find the reason of this disagreement. Also, we study how the number of heavy particles and the number of fast protons influence the probability of the production of an even or odd number of pions in the whole sample of events, including the 'white stars'.

2. EXPERIMENT AND RESULTS

The experimental material used in this work is produced by the BATAVIA collaboration. Details about the experiment are described in [2,3]. The material contains 183 interactions of 200 GeV/c, 405 interactions of 300 GeV/c and 301 interactions of 400 GeV/c protons with emulsion nuclei. The corresponding numbers of 'white stars' are 36, 72 and 54, respectively. The experimental rate of 'white stars' events, at the level of 18 %, is about four times higher than prediction of QGSM, assuming that 'white' stars are events where charged pions are emitted only.

Since the QGSM systematically predicts lower rate of such events, the sample of 'white stars' has been treated by the following procedure. As a first, we supposed that in the experimental sample one of the shower particles could be a proton ($n_s = n_\pi + 1$). So in MC simulations the 'white stars' were defined as events of type: $p + Em \to p + n_\pi\pi$ or $p + Em \to n_\pi\pi$. This idea was strongly supported by the results of MC simulations on angular and multiplicity distributions of secondary particles where we found significant number of fast protons that in the experiment were identified as shower particles, especially at small angles, [5].

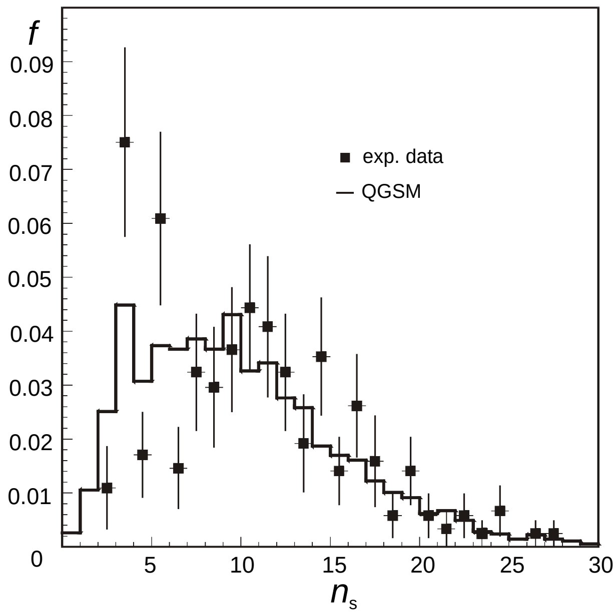

Fig.1. The experimental multiplicity distribution of the shower particles ('white stars') compared with the predictions of the QGSM .

The comparison of results of this procedure and experimental data is shown in Fig. 1. Note that both distributions represent the sum of corresponding distributions at 200, 300 and 400 GeV/c. We can see that, after the above procedure, the QGSM practicaly reproduce the experimental rate of 'white stars'. However, Fig. 1 also shows that problem of 'even-odd effect' remains open.

Such an asymmetry could be connected with the mechanism of coherent particle production. So, as the next step, we excluded the coherent events from the experimental data. The criterion for the coherent event is $\Sigma_i \sin \vartheta_i \leq 0.30$, where ϑ_i denotes the angle between the secondary pion and the projectile [4]. Applying this in the MC simulations, we found that the sample of the generated events also contains events satisfying this criterion, though such type of interaction is not included in the model. The application of the criterion on the generated events reduced their number for about 15%. This fact indicates that this criterion can't be used as absolutely correct. It probably reduces the number of incoherent events in the experimental sample as well.

Results of this correction are shown in Fig. 2. The remarkable effect appears only for $n_s = 3$. At all other low multiplicities the odd number of pions is still more probable than the even one, in the experiment and in the model. The even number of pions dominates at high multiplicities. So, we conclude that the'even-odd effect', seen in 'white stars' events, cannot be fully explained by the coherent particle production. This opens interesting questions about the role of the asymmetry in total experimental sample. In what follows, we study the 'even-odd effect' as a function of the excitation of target nucleus and impact parameter value.

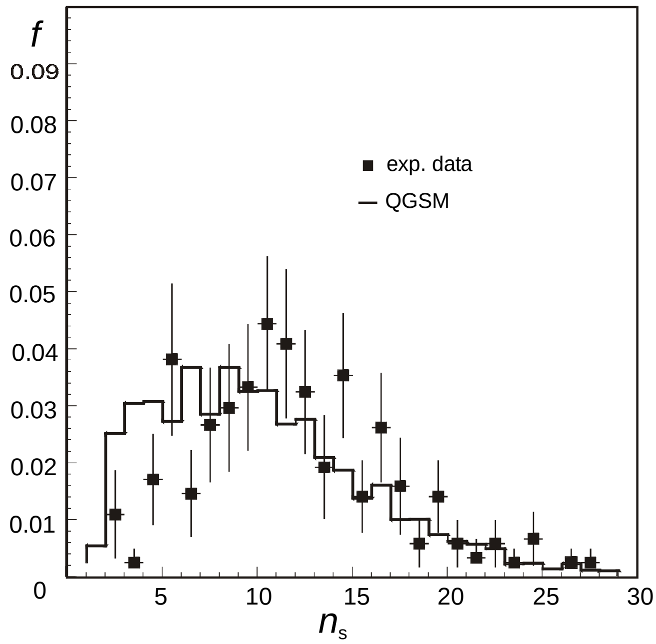

Fig. 2. The experimental multiplicity distribution of the shower particles ('white stars') compared with the predictions of the QGSM, both without coherent events.

In Fig. 3 we compare the sample of 'white stars' with the total experimental sample.

For each odd multiplicity of shower particles, f_{odd}, we found the mean value of its even neighbors,

$$< f_{\text{even}} >= \frac{(f_{odd-1} + f_{odd+1})}{2} , \qquad (1)$$

and determined the ratio

$$R_1 = \frac{f_{odd}}{< f_{even} >} . \qquad (2)$$

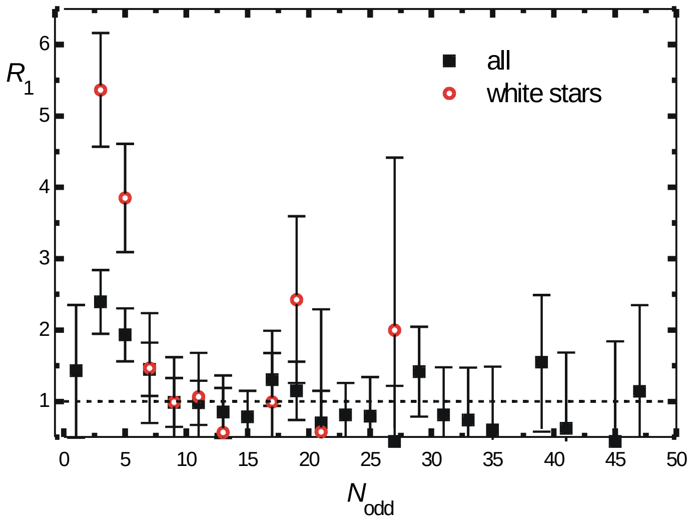

Fig. 3. The 'even-odd' effect in 'white stars' and in the whole sample.

It is obvious that for all low multiplicities the ratio $R_1 > 1$, especially for the 'white stars'. In this procedure the coherent events were not excluded from the experimental data.

Note that the emulsion is a composite target with $<A> = 67$ and $<Z> = 29$. It contains light (H, C, N and O) and heavy (Br and Ag) nuclei. Events with $n_h \le 8$ can be assumed as the interactions on any of emulsion nuclei. If $n_h > 8$ the interactions is obviously with some heavy (bromine or silver) nucleus and the characteristics of the target are $<A> = 94$ and $<Z> = 41$. For the events with $n_h > 35$ target is only the ${}^{47}_{108}\text{Ag}$ nucleus.

However, if we present the ratio

$$R_2 = \frac{N_{ev}^{\;odd}}{N_{ev}^{\;even}} , \qquad (3)$$

the remarkable difference appears, and this is shown in figures 6 and 7. Unfortunately, the small number of events leads to the large fluctuations and statistical errors and do not allow us to say if the ratio $R_2 = f(n_h)$ is sensitive to the structure of the target. For the whole sample $<R_2> = 1.05 \pm 0.07$.

The function $R_2 = f(n_g)$, taking errors into account, demonstrates an interesting nonmonotone shape. For small values of n_g the ratio $R_2 \approx 1$, but in the region where the target is the heavy nucleus, the shape changes and there appears to be a maximum. If we assume that the number of fast protons is related to the impact parameter, we can suppose that the function $R_2 = f(n_g)$, in an experiment with higher statistics, could give additional information about the target, which is especially interesting in the case of composite targets.

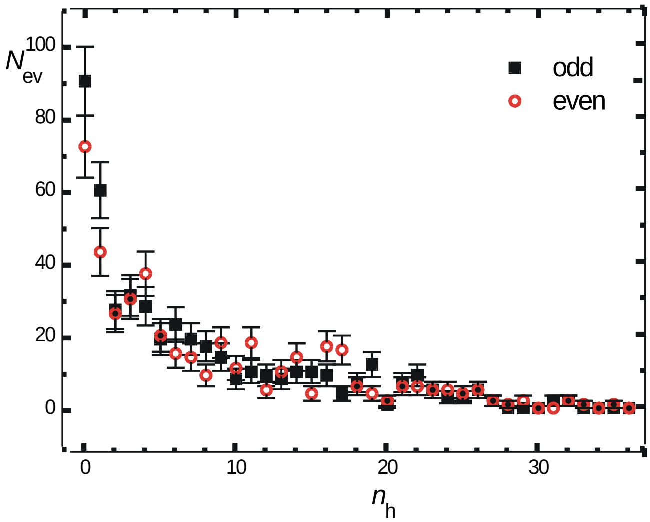

Fig. 4. The number of events with an even or odd number of shower particles as the function of n_h for all events.

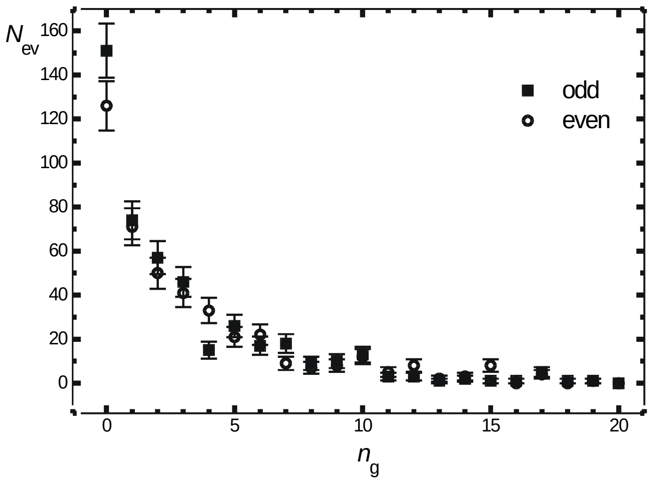

Fig. 5. The number of events with an even or odd number of shower particles as the function of n_g for all events.

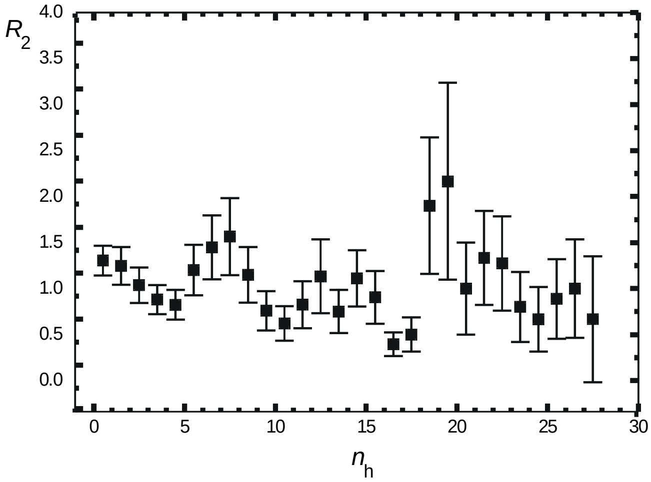

Fig. 6. The ratio of the number of events with an odd and even shower particles multiplicity for the given value of n_h.

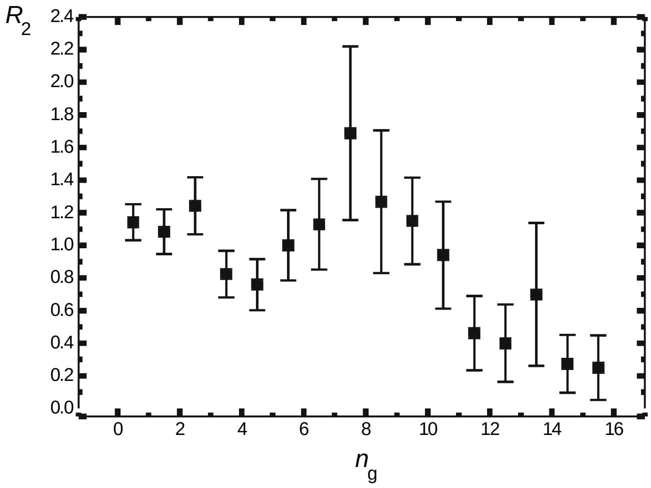

Fig. 7. The ratio of the number of events with an odd and even shower particles multiplicity for the given value of n_g.

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DISTRIBUCIJE MULTIPLICITETA RELATIVISTIČKIH ČESTICA U SUDARIMA PROTONA OD 200-400 GEV/C, SA EMULZIJOM

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Analizirana je asimetrija pojavljivanja parnih i neparnih multipliciteta sekundarnih piona nastalih u interakcijama protona sa nuklearnom emulzijom na 200, 300 i 400 GeV/c. Utvrđeno je da mehanizam koherentne produkcije čestica ne objašnjava u potpunosti broj događaja sa neparnim multiplicitetima piona u tzv. 'belim zvezdama'. Dat je prikaz zavisnosti asimetrije od multipliciteta teških čestica i brzih protona.

Ključne reči: *par-nepar efekat, hadron-jezgro sudari na visokim energijama*